Culvert Analysis with HEC-HMS and HEC-RAS

Presenter:

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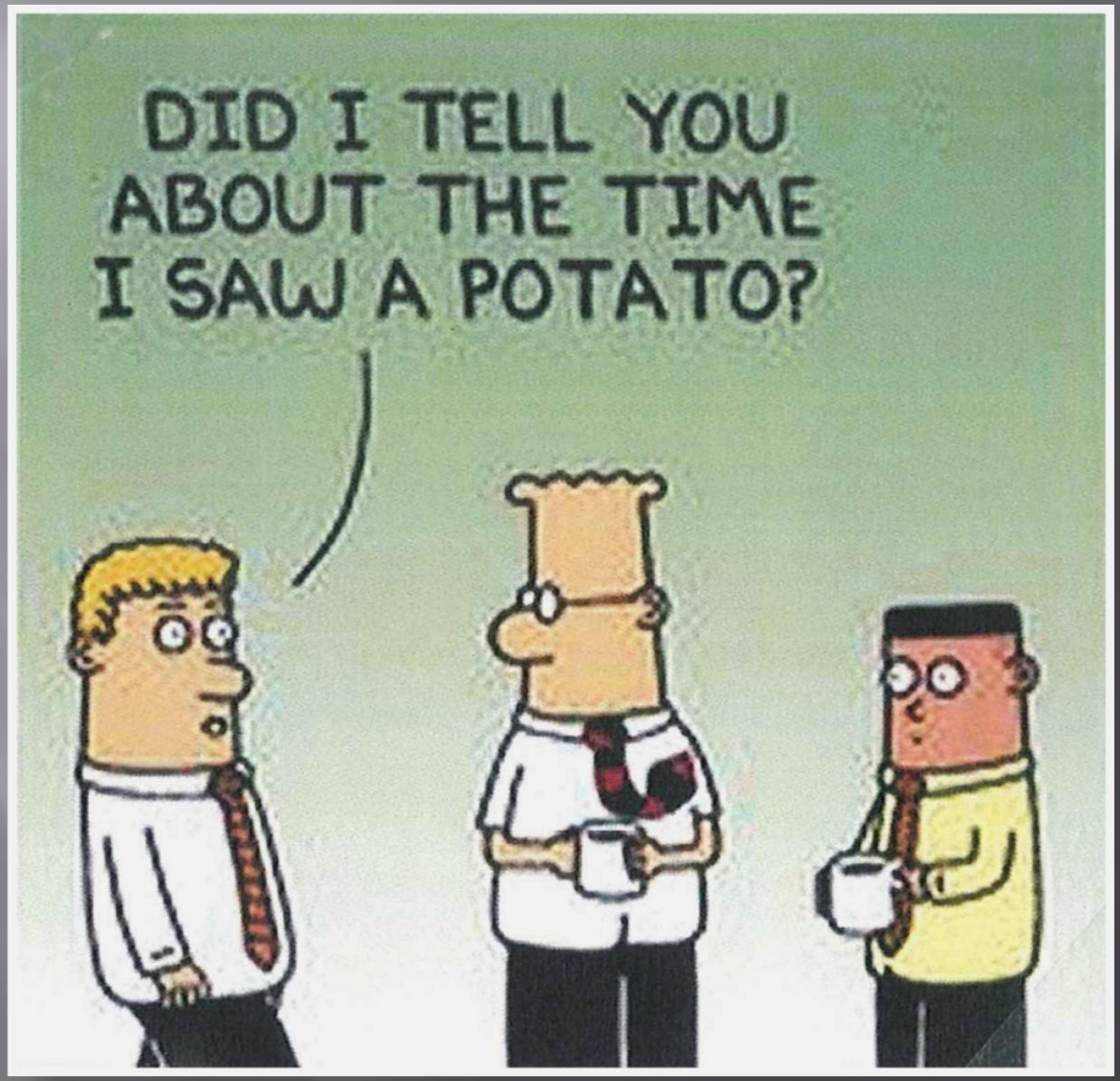
DID I TELL YOU
ABOUT THE TIME
I SAW A POTATO?

Culvert Analysis with HEC-HMS and HEC-RAS

1) Background	• Tributary 7 Surprises • City-Wide Evaluation • Cribbs Mill Creek
2) Cribbs Mill Creek	• Culvert without Evaluation • Basin • Opportunity
3) Analysis	• Surface Flow • Storm Sewer • Pond Model
4) Results	• Consistent Results • Removed Homes from SFHA • Approval

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Why can't I rebuild?

We worked on the LOMR for Cribbs Mill Creek Tributary 7 after the tornado of April 27, 2011. We discovered several problems that delayed the project.

People wanted to rebuild after the tornado.

Cribbs Mill Creek Tributary 7 presented surprises.

Chapter One Background

Who put that culvert there?

Trib 7 Surprise 1

- Culvert reach
- Two sizes
- Approximately 800 feet long
- Within parking lot (destroyed shopping center)
- Effective model: open channel

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How did that happen?

Trib 7 Surprise 2

- Apartments
- Culvert changed size

Chapter One Background

Oh, so that's how they did it.

Trib 7 Surprise 2

- Constructed a concrete box to connect two separate installations

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E431 is strange.

Trib 7 Surprise 3:

The effective E431 model analyzed the tributary in multiple parts. One part analyzed the tributary to a point downstream from McFarland Boulevard. A new analysis then picked up on the upstream side of McFarland Boulevard.

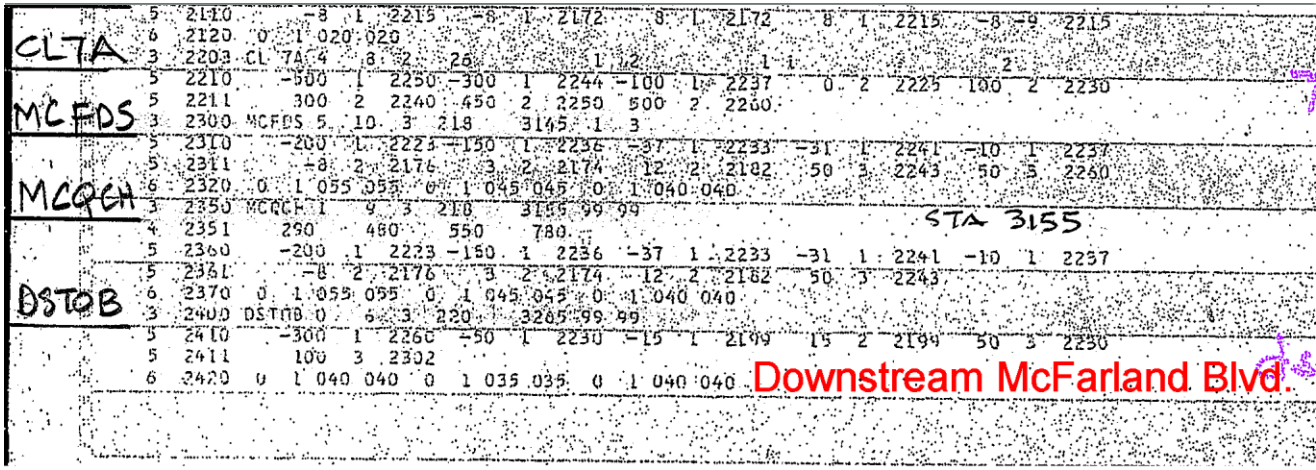
Downstream elev: 224.00 (calculated)

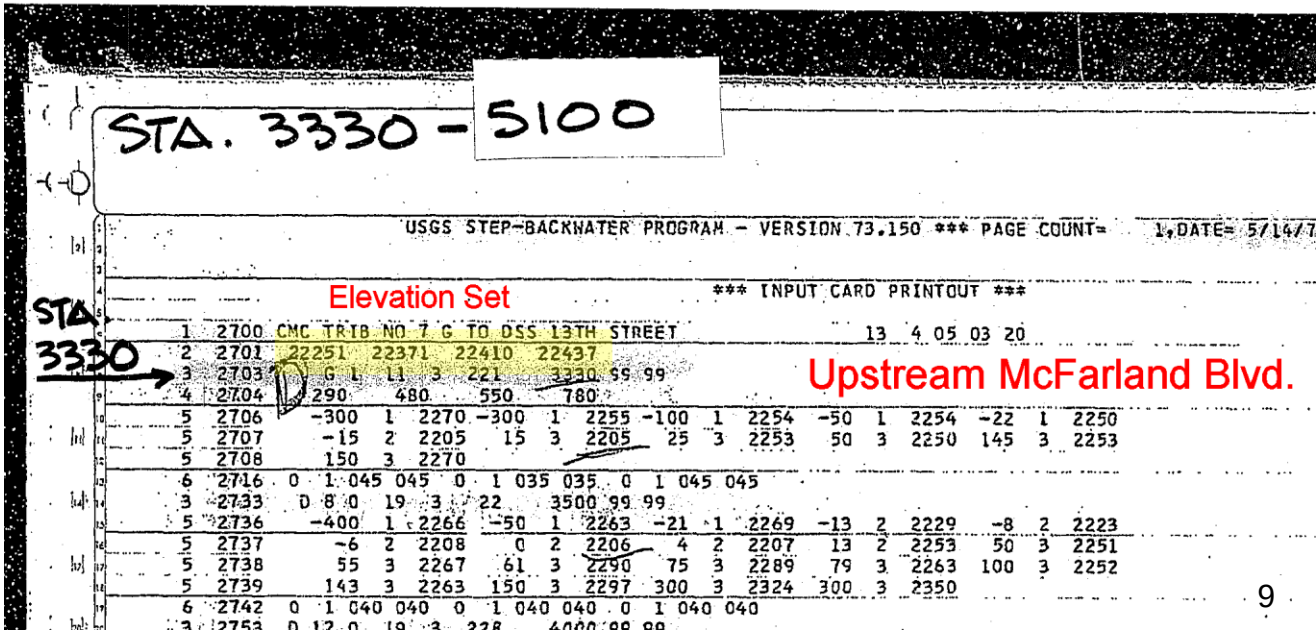
Upstream elev: 224.10 (manually set)

That is so hard to read.

Trib 7 Surprise 3:

The E431 records consisted of scanned printouts. There were no electronic models or maps. Handwritten notes on the printouts often gave the best indication of the location. For example, the handwritten notes in the right margin are “7th Ave E” and “dss McFarland” (only parts of the notes are shown to the right in purple).





Chapter One
Background

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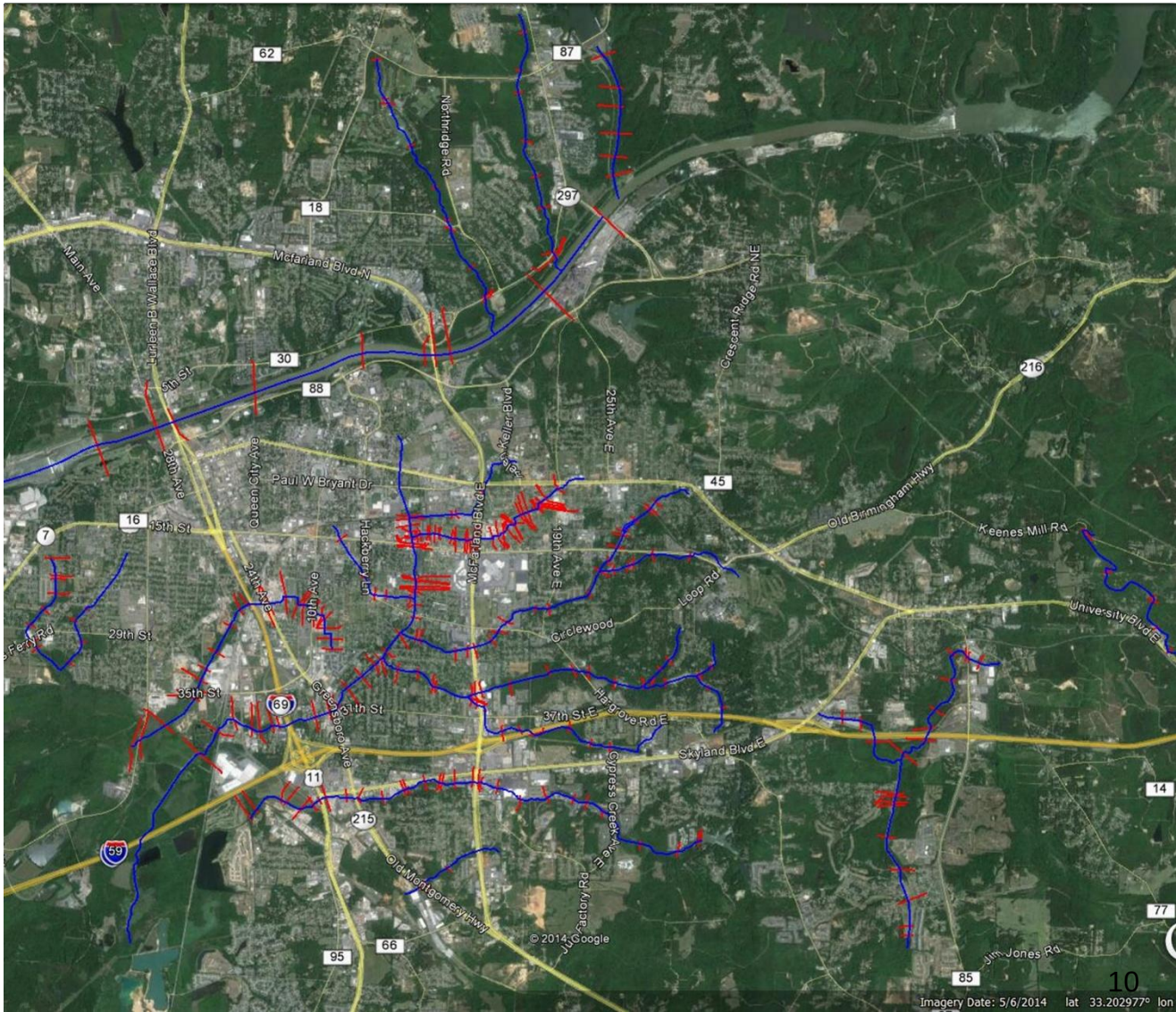
We need a City-wide evaluation.

22 Models:

- Bee Branch
- Black Warrior River (City)
- Black Warrior River Tributary No. 2
- Black Warrior River Tributary No. 3
- Cottondale Creek Tributary No. 1
- Cottondale Creek Tributary No. 1A
- Cribbs Mill Creek
- Cribbs Mill Creek Tributary No. 1
- Cribbs Mill Creek Tributary No. 2
- Cribbs Mill Creek Tributary No. 3
- Cribbs Mill Creek Tributary No. 4
- Cribbs Mill Creek Tributary No. 5
- Cribbs Mill Creek Tributary No. 5A
- Cribbs Mill Creek Tributary No. 5B
- Cribbs Mill Creek Tributary No. 6
- Cribbs Mill Creek Tributary No. 7
- Cypress Creek
- Moody Swamp Tributary No. 1
- Moody Swamp Tributary No. 2
- Moody Swamp Tributary No. 3
- North River
- Rum Creek Tributary No. 1

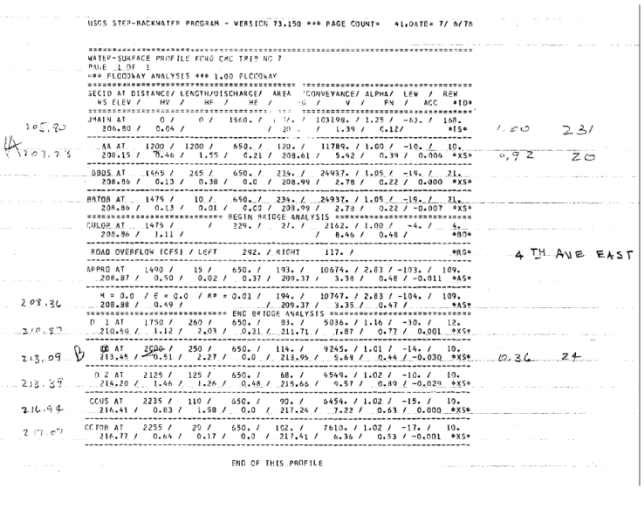


Chapter One
Background

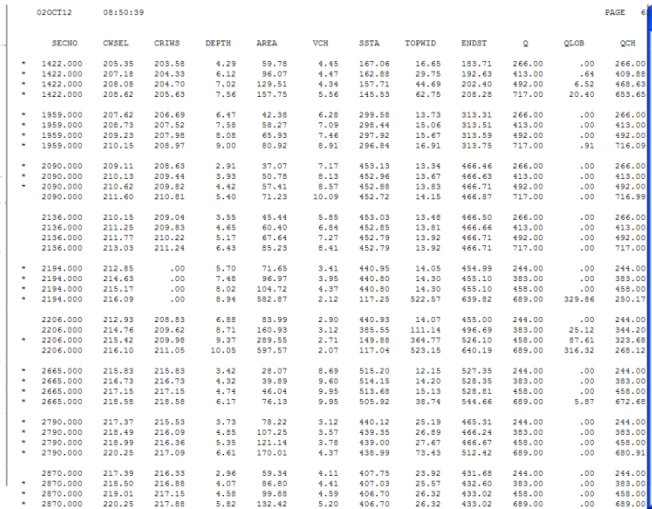
I still can't see the redhead.

In order to see the results, we converted each model to HEC-RAS.

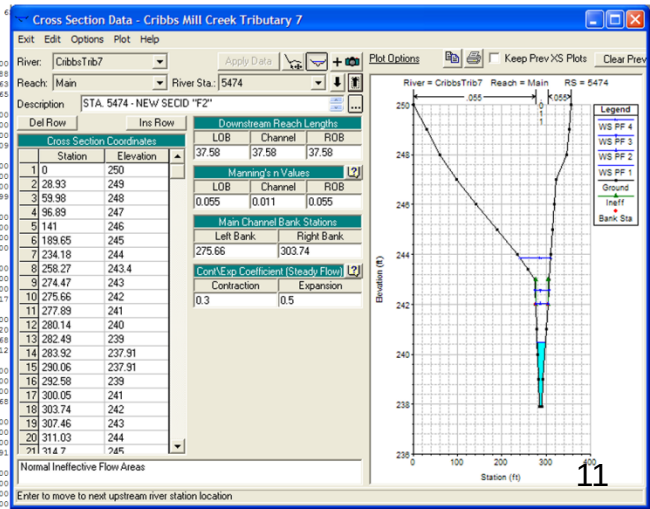
E431



HEC-2



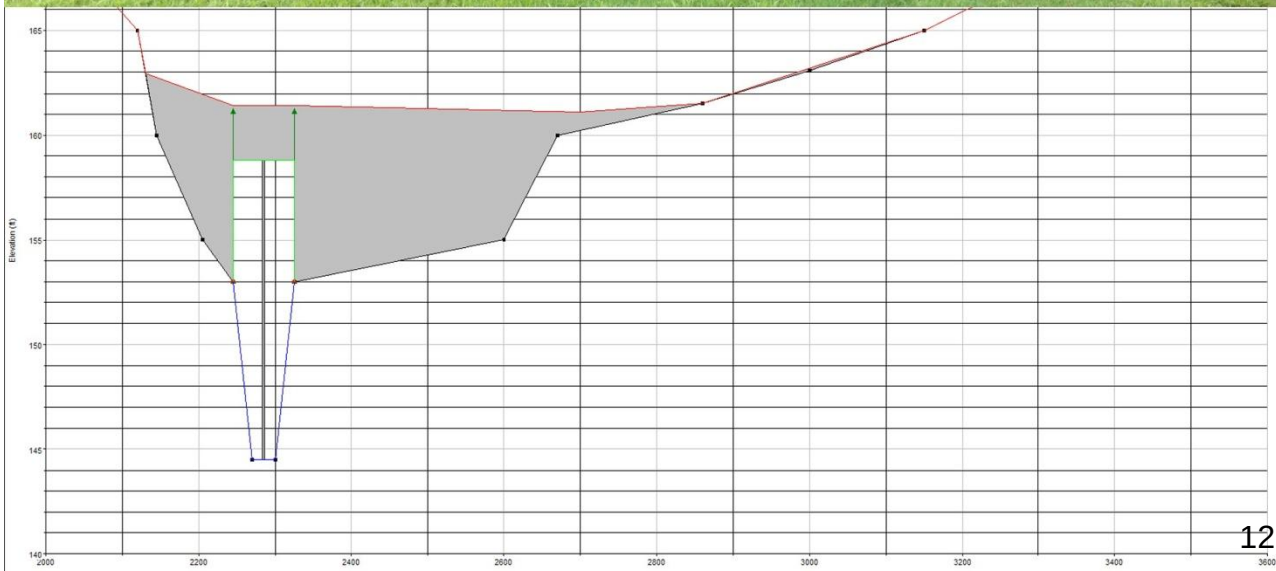
HEC-RAS



Chapter One Background

Now I see. Thanks, much better.

After converting the models to HEC-RAS, we could compare the graphical images to photos of the actual structures. Obviously, this bridge had changed.



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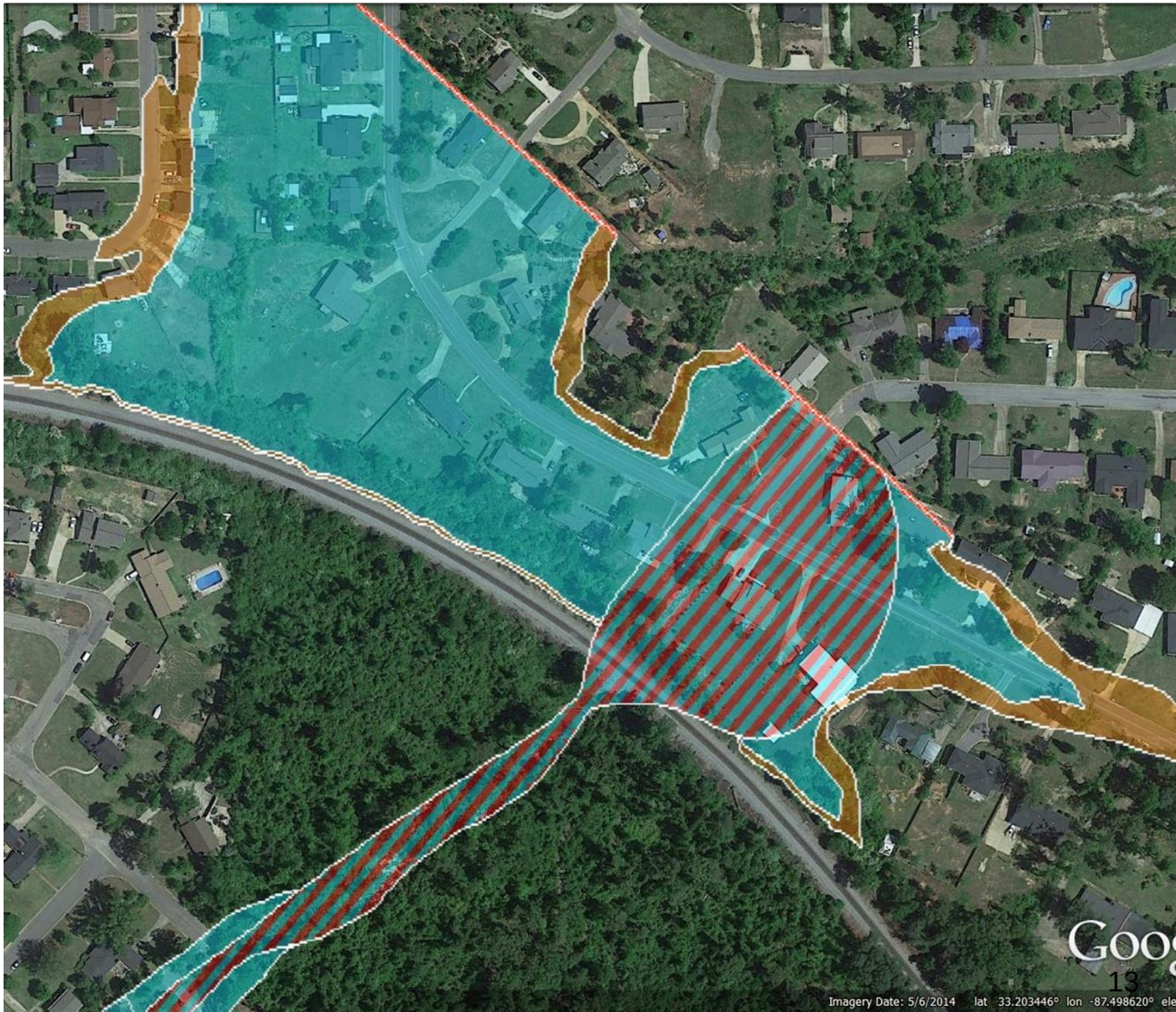
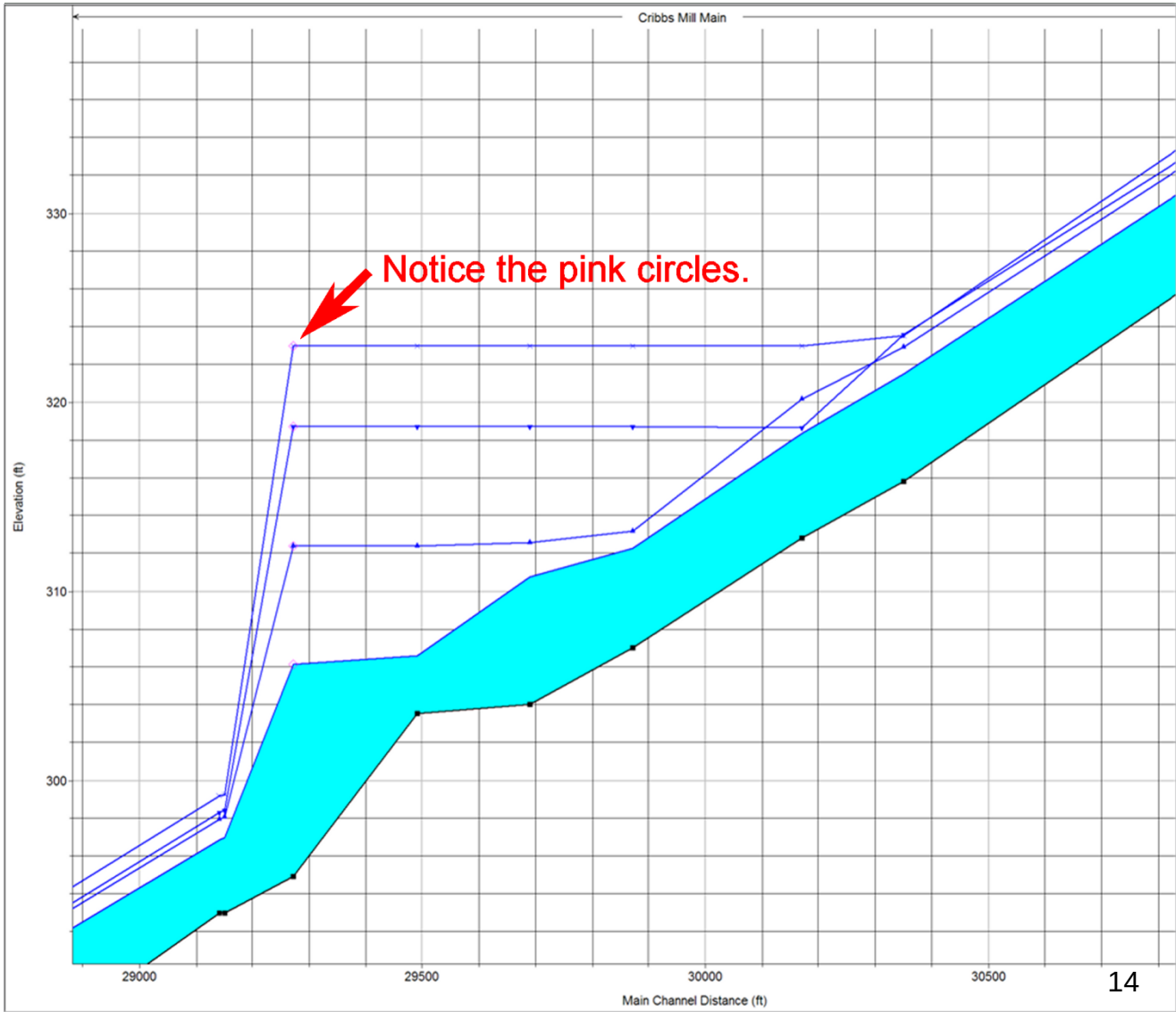
Is that culvert big enough?

Eventually, we looked at the upstream end of Cribbs Mill Creek. It appeared that the railroad acted as a dam and flooded the Arcadia neighborhood.



There's no culvert analysis.

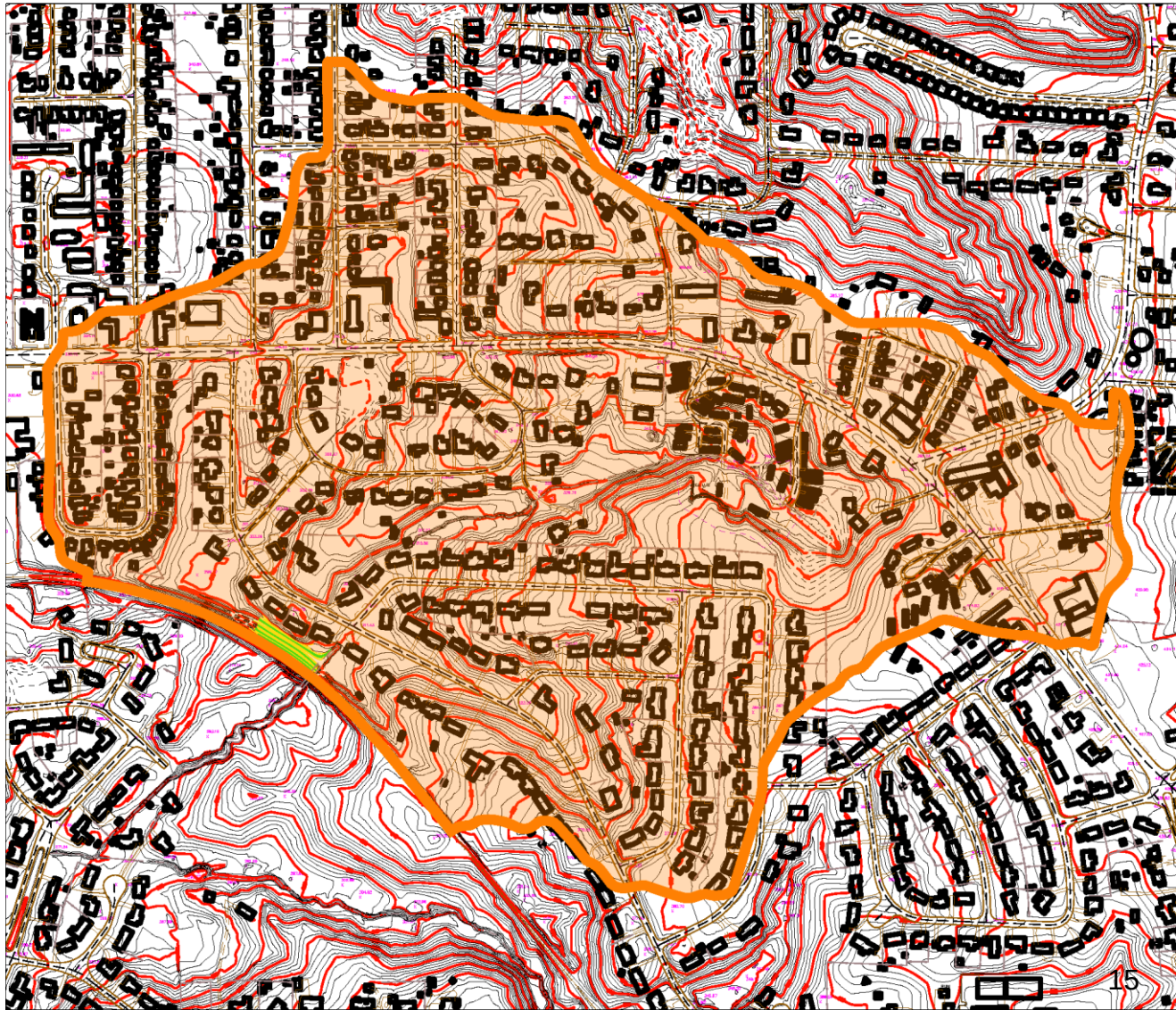
The model indicated that the flood elevations were manually set on the upstream side of the railroad. There was no culvert analysis within the model. Initially, we thought that we might be able to lower the base flood elevation by 12 feet.



Chapter Two
Cribbs Mill Creek

The work of overzealous modelers.

Normally, a stream might not be studied if the watershed is less than one square mile. At the railroad, the Cribbs Mill Creek watershed is only 0.3 square miles.



Chapter Two
Cribbs Mill Creek

Confirmation: No culvert analysis in the model.

A previous LOMR had converted the E431 model to HEC-2. The focus of that LOMR was not on the railroad or the Arcadia neighborhood.

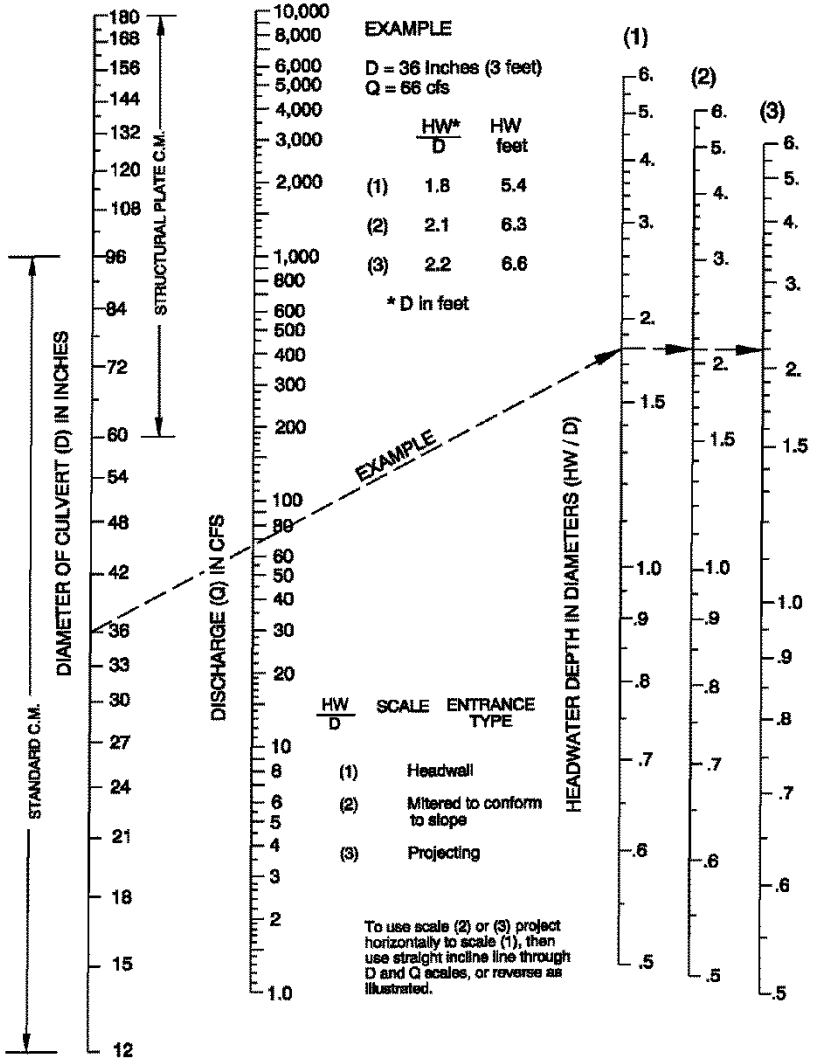
```
        NO CULVERT INPUT DATA AVAILABLE TO FORMULATE A MODEL.

        HEC-2 SECID "BBTOB" AT HEC-2 STA. 29100.


QT        4        360        590        690        970
NC    0.100      0.100      0.100       0.10       0.30
X1    29100          7      50.00     115.00       10.0       10.0       10.0
GR    305.2        000      301.5      50.00      295.0       60.0      293.0      100.0      300.7
GR    302.6      200.0      309.2      241.0

        BEGIN CROSS SECTION INPUT FOR E431 MODELS DATED 6/02/1976 & 6/24/1976.
        LOCATION IS ENTRANCE/UPSTREAM FACE OF CULVERT BENEATH SOUTHERN RR TRACKS
        RR CENTERLINE STATION IS APPROXIMATELY 29160.
        X5 ENTRY WILL BE REQUIRED DUE TO THE ABSENCE OF ANY CULVERT INPUT DATA.
        THIS METHOD OF USING WATER SURFACE ELEVATION PRESETS IS A TYPICAL
          PROCEDURE AND THE USUAL METHOD IN THE E431 MODEL DATA WHEN A CULVERT
          OR DRAINAGE STRUCTURE IS ENCOUNTERED .

        E431 SECID "BD" AT E431 STA. 38150 =
        HEC-2 SECID "AI" AT HEC-2 STA. 29220.

        HEC-2 SECID "AI" AT STA. 29220.

1
    12MAR12      17:46:31


QT        4        360        590        690        970
NC    0.080      0.080      0.120       0.10       0.30
X1    29220         15     278.00     294.00      120.0      120.0      120.0
X5        4     306.09     312.37     318.69     323.00
GR    324.6        000      312.6       47.0      310.3       83.0      309.8      133.0      305.4
GR    303.5      233.0      303.4      278.00      295.4      280.0      295.1      283.0      294.9
GR    303.9     294.00      305.5      374.0      309.4      394.0      316.5      412.0      324.6

        E431 SECID "BE" AT E431 STA. 38370 =
        HEC-2 SECID "BE" AT HEC-2 STA. 29440.
        CENTERLINE ARCADIA DRIVE = STA. 29460 (+/-).


QT        4        360        590        690        970
NC    0.080      0.080      0.080       0.10       0.30
X1    29440         17     581.00     601.00      220.0      220.0      220.0
GR    326.0        000      322.3       0.10      320.1       91.0      317.7      191.0      315.5
GR    311.1      491.0      309.3     581.00      303.5      586.0      303.5      596.0      309.3
GR    309.7      641.0      310.5      691.0      313.5      791.0      315.5      891.0      315.6
```

Is that the correct approach?

A nomograph, using peak flow, is usually the proper approach for a culvert analysis. The equations are built into HEC-RAS.

FYI:

- 60" CMP
- 690 cfs
- HW/D = 10



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Maybe it's a little like a water tower

Essentially, we find the correct pressure to achieve a desired flow.

But what if we have a place to temporarily store incoming water? If we can store some water, then we don't need to pass the peak.

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This place has lots of room for storage.

A large basin on the upstream side of the railroad provides room for storage.

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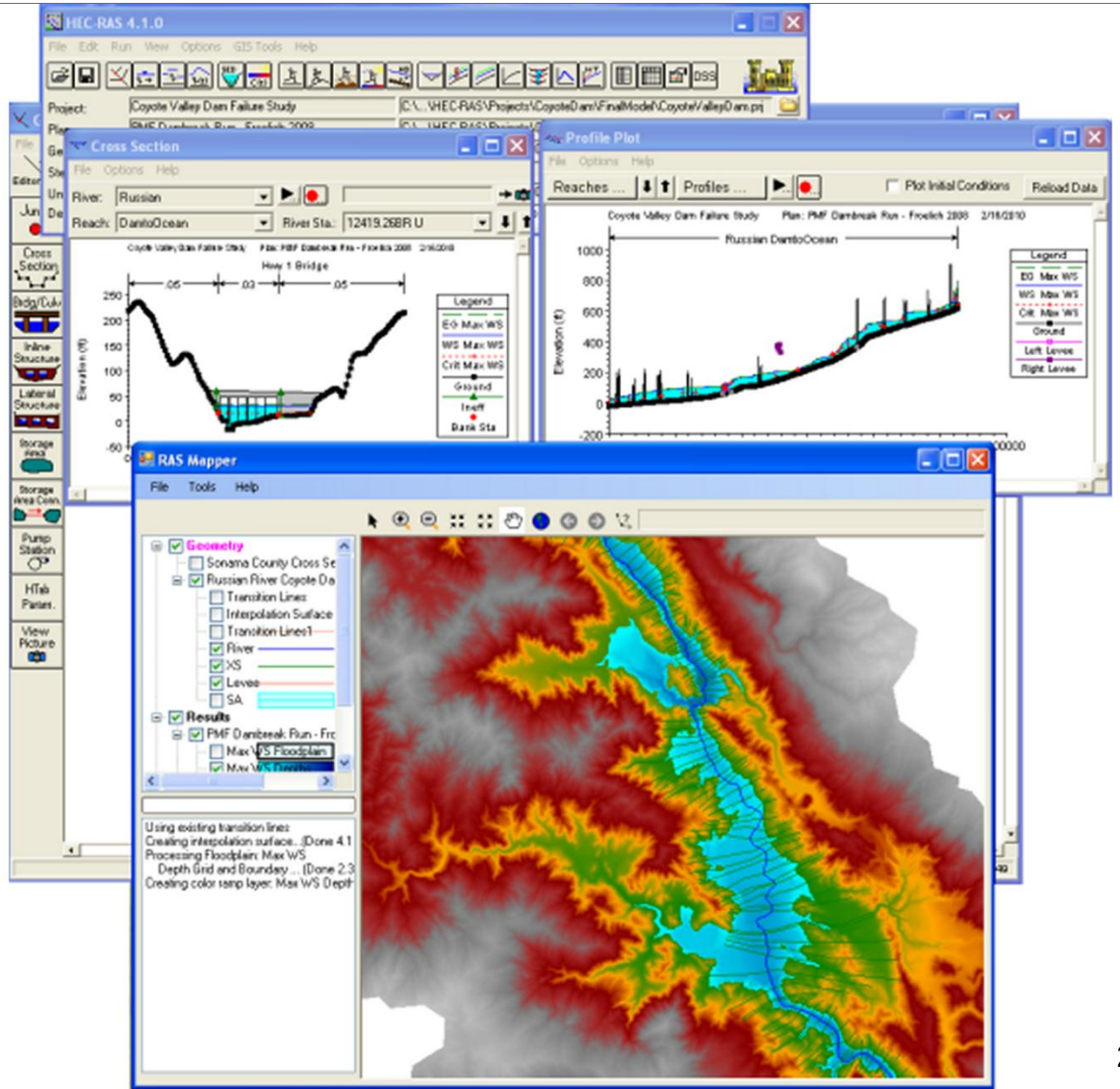
There's more than one way …

There are probably a multitude of ways to analyze the railroad culvert. This presentation provides one successful way.

Chapter Two
Cribbs Mill Creek

There can be only one … or not.

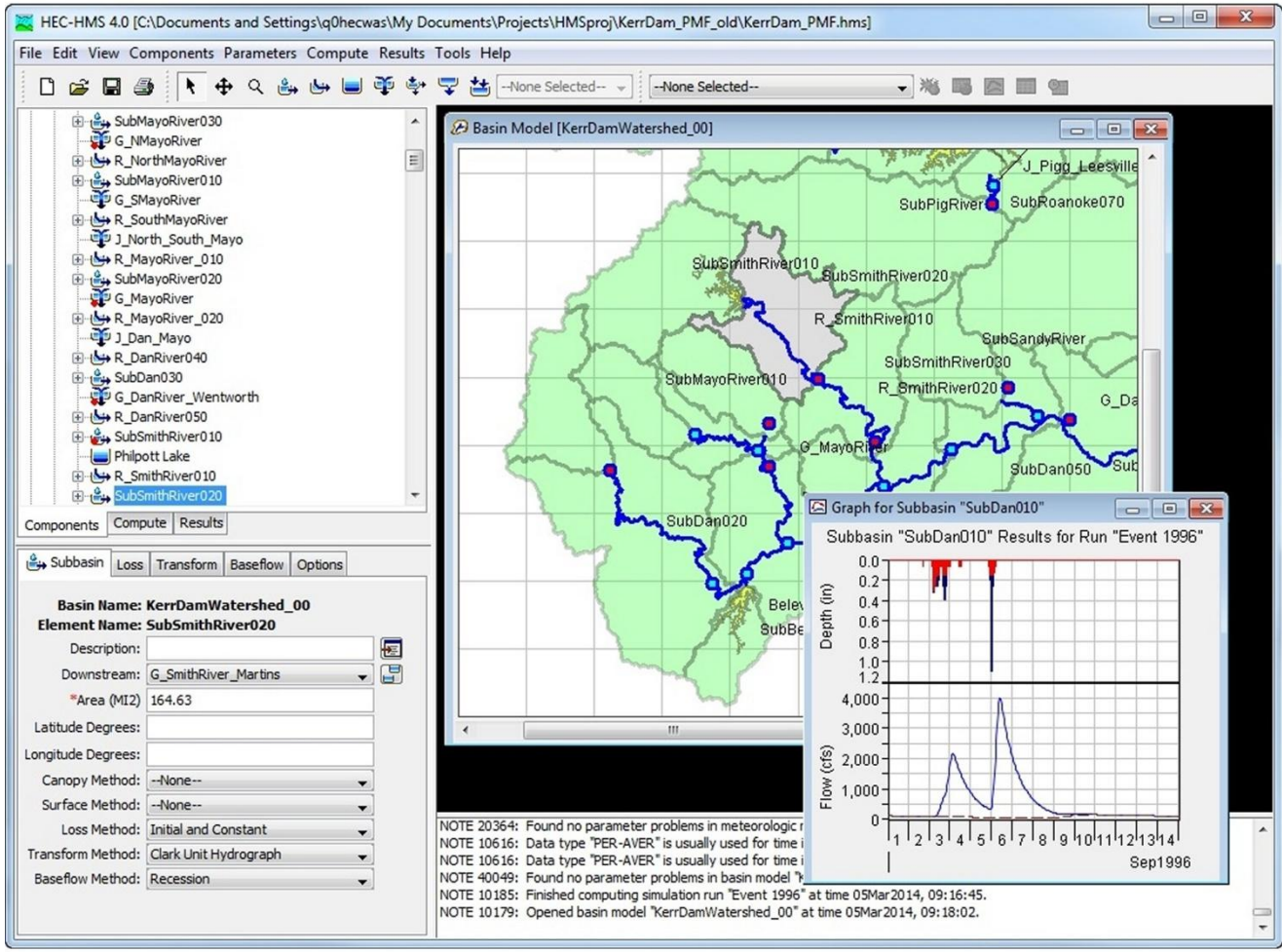
HEC-RAS is a great tool for analyzing steams, but there is no option for a pond model.



Chapter Two
Cribbs Mill Creek

Actually, there are other ways.

HEC-HMS provides a way to analyze watersheds and includes pond modeling options.



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This is how it looks.

The view is from the railroad, looking upstream. The pipe to the right is the storm sewer. The left pipe connects to a street inlet. The railroad culvert is not visible at the bottom of the photo.

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This is how it looks.

The view is from the street, looking downstream. The railroad culvert is in the shadows.

60” Corrugated Steel Pipe

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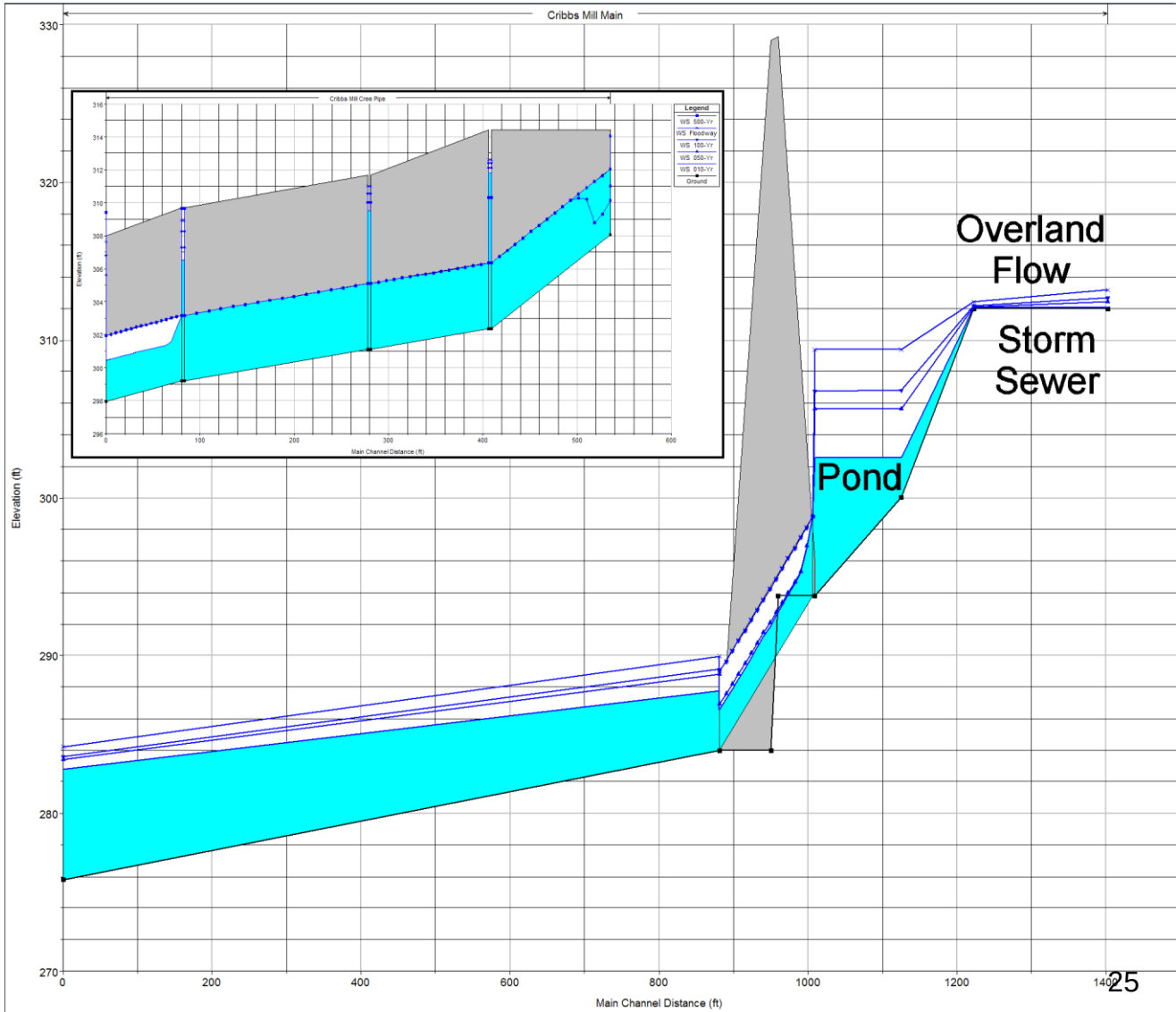
Break it into parts.

The system has three main parts:
- Pond
- Overland Flow
- Storm Sewer



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It's a balancing act.

- The analysis involves several iterations.
- The pond level controls the storm sewer flows.
- We need the HEC-RAS model to calculate the pond flows, but we need the pond flows to set up the model

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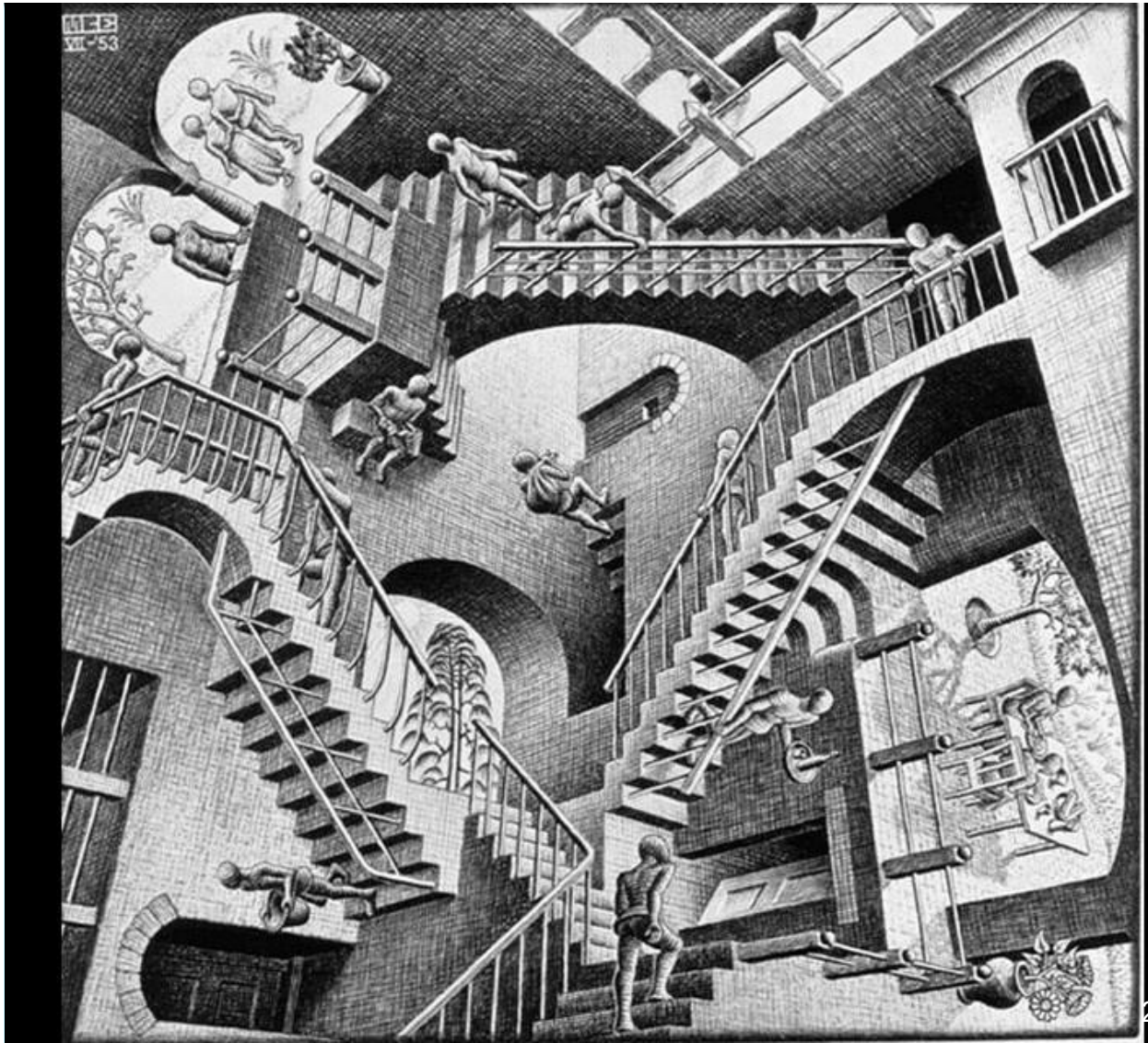
Confused yet?

Actually it's not that difficult. The pond flows are almost independent because the railroad culvert is so steep that it remains inlet controlled. However, the pond levels do control the storm sewer flows.



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2, 4, 6, 8 …

Use HEC-RAS to find flow rates at 2-ft increments.

Profile Output Table - Standard Table 1

File Options Std. Tables User Tables Locations Help

HEC-RAS Plan: Profiles River: Cribbs Mill Reach: Main

Reload Data

Reach	River Sta	Q Total (cfs)	Min Ch El (ft)	W.S. Elev (ft)	Crit W.S. (ft)	E.G. Elev (ft)	E.G. Slope (ft/ft)	Vel Chnl (ft/s)	Flow Area (sq ft)	Top Width (ft)	Froude # Chl
Main	29440	92.00	312.00	312.20	312.20	312.29	0.028938	4.28	47.58	249.17	1.70
Main	29440	92.00	312.00	312.20	312.20	312.29	0.028938	4.28	47.58	249.17	1.70
Main	29440	92.00	312.00	312.20	312.20	312.29	0.028938	4.28	47.58	249.17	1.70
Main	29340	92.00	300.00	301.10	301.10	301.61	0.025309	5.77	15.95	15.61	1.01
Main	29340	92.00	300.00	301.10	301.10	301.61	0.025067	5.75	16.00	15.62	1.00
Main	29340	92.00	300.00	301.10	301.10	301.61	0.025288	5.77	15.96	15.62	1.00
Main	29340	92.00	300.00	301.92		302.07	0.003874	3.12	29.51	17.21	0.42
Main	29340	92.00	300.00	303.99		304.02	0.000325	1.34	68.58	20.51	0.13
Main	29340	92.00	300.00	306.00		306.01	0.000080	0.82	112.69	23.51	0.07
Main	29340	92.00	300.00	308.00		308.01	0.000024	0.56	173.07	36.79	0.04
Main	29340	92.00	300.00	310.00		310.00	0.000008	0.38	341.43	131.85	0.02
Main	29340	92.00	300.00	312.00		312.00	0.000002	0.23	629.88	156.42	0.01
Main	29220	37.10	293.81	296.00	294.95	296.06	0.001950	1.97	18.83	13.35	0.29
Main	29220	94.70	293.81	298.00	295.69	298.04	0.000693	1.56	60.56	28.36	0.19
Main	29220	157.70	293.81	300.00	296.27	300.02	0.000243	1.24	126.94	38.04	0.12
Main	29220	199.30	293.81	302.00	296.58	302.01	0.000094	0.94	212.20	47.35	0.08
Main	29220	231.60	293.81	304.00	296.78	304.01	0.000043	0.73	316.28	56.64	0.05
Main	29220	259.90	293.81	306.00	296.96	306.00	0.000018	0.58	516.87	144.16	0.04
Main	29220	285.50	293.81	308.00	297.09	308.00	0.000007	0.44	952.19	294.24	0.02
Main	29220	308.90	293.81	310.00	297.20	310.00	0.000003	0.31	1573.73	328.38	0.02
Main	29220	330.70	293.81	312.00	297.31	312.00	0.000001	0.24	2277.88	375.59	0.01
Main	29155	Culvert									
Main	29090	37.10	284.00	288.54		288.54	0.000017	0.34	110.46	30.38	0.03
Main	29090	94.70	284.00	288.70		288.71	0.000096	0.82	115.21	30.79	0.07
Main	29090	157.70	284.00	288.86		288.88	0.000236	1.31	120.10	31.22	0.12
Main	29090	199.30	284.00	288.96		289.00	0.000350	1.62	123.31	31.49	0.14
Main	29090	231.60	284.00	289.03		289.09	0.000448	1.84	125.69	31.69	0.16
Main	29090	259.90	284.00	289.10		289.16	0.000539	2.03	127.75	31.86	0.18
Main	29090	285.50	284.00	289.16		289.23	0.000624	2.20	129.64	32.02	0.19
Main	29090	308.90	284.00	289.21		289.29	0.000705	2.35	131.28	32.16	0.21
Main	29090	330.70	284.00	289.26		289.35	0.000782	2.49	132.80	32.28	0.22
Main	28290	900.00	275.80	283.62	283.25	284.32	0.036162	7.40	161.39	81.95	0.53
Main	28290	900.00	275.80	283.62	283.25	284.32	0.036162	7.40	161.39	81.95	0.53
Main	28290	900.00	275.80	283.62	283.25	284.32	0.036162	7.40	161.39	81.95	0.53
Main	28290	900.00	275.80	283.62	283.25	284.32	0.036162	7.40	161.39	81.95	0.53
Main	28290	900.00	275.80	283.62	283.25	284.32	0.036162	7.40	161.39	81.95	0.53
Main	28290	900.00	275.80	283.62	283.25	284.32	0.036162	7.40	161.39	81.95	0.53
Main	28290	900.00	275.80	283.62	283.25	284.32	0.036162	7.40	161.39	81.95	0.53
Main	28290	900.00	275.80	283.62	283.25	284.32	0.036162	7.40	161.39	81.95	0.53
Main	28290	900.00	275.80	283.62	283.25	284.32	0.036162	7.40	161.39	81.95	0.53

Total flow in cross section.

2, 4, 6, 8 … for the areas.

Find the basin areas at 2-ft increments. Exclude the areas of the structure footprints.

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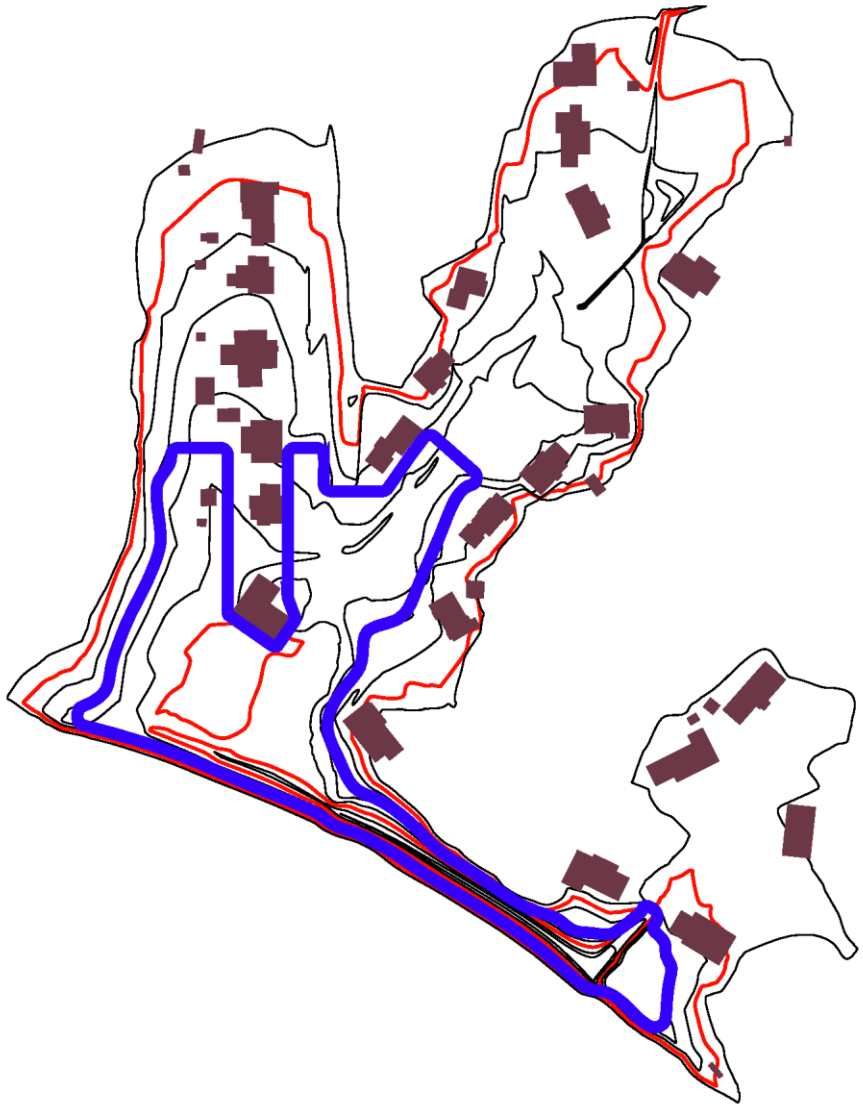
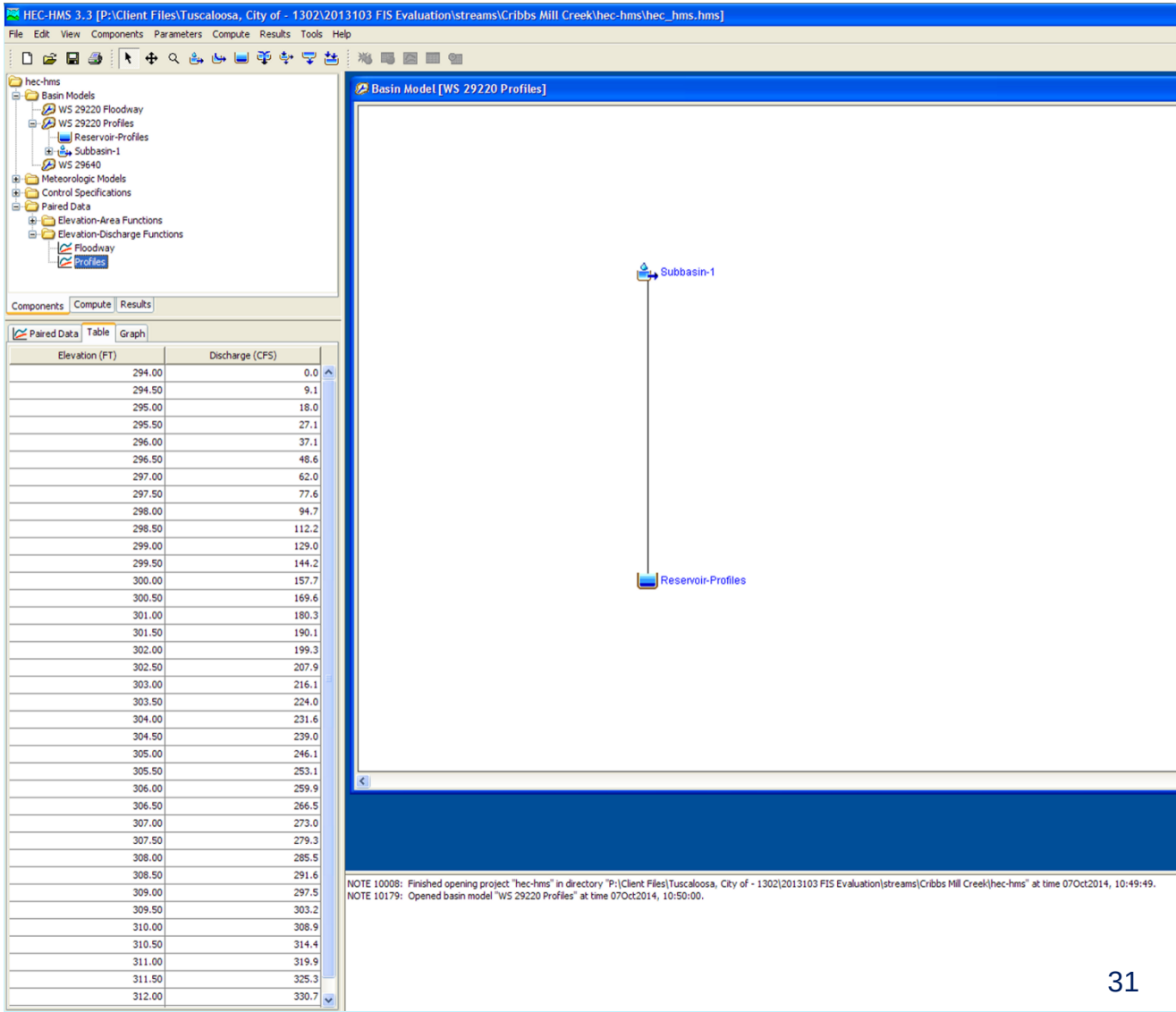
Special floodway.

The floodway is found by trial. It's the basin that avoids all structures and creates no more than one foot of surcharge. Just as with a HEC-RAS riverine analysis, the floodway walls are vertical.



Building the pond.

Use the flows (and basin areas from the topo map) to create the HEC-HMS pond.



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You better check that.

The HEC-HMS peak inflow to the pond is 658 cfs (curve number method). The value from the USGS regression equation is 668 cfs. The flow rate in the effective model was 690 cfs.

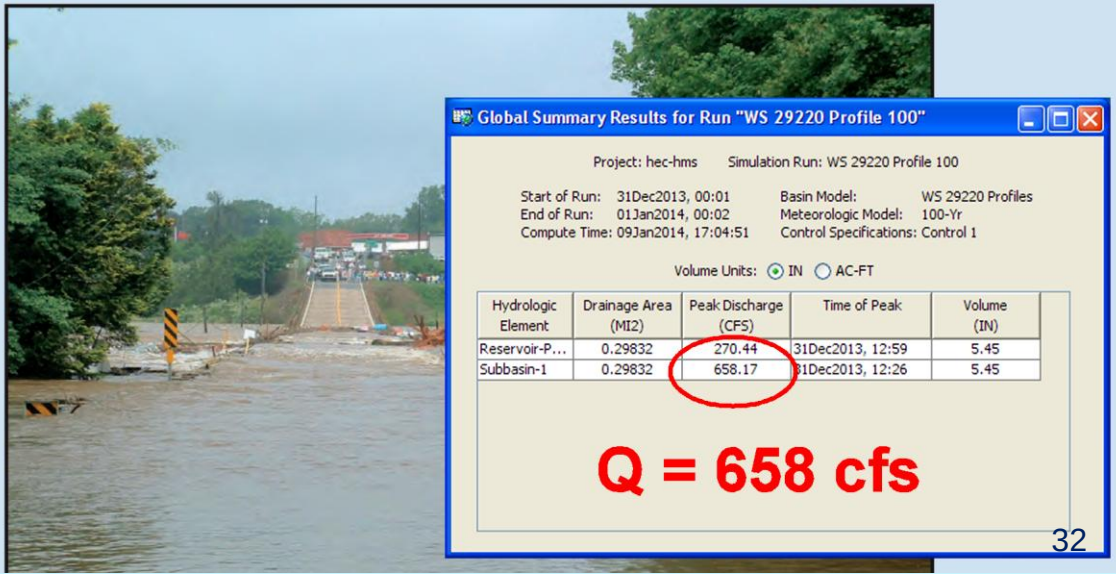
Notice that we use the peak discharge from the pond as the flow rate in HEC-RAS: 270 cfs.

USGS
science for a changing world

Prepared in cooperation with the Alabama Department of Transportation

Magnitude and Frequency of Floods in Alabama, 2003

Q = 668 cfs



Where does that get us?

The basin behind the railroad attenuates the flow from 658 cfs to 270 cfs.

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Hey, it worked!

The elevations predicted by HEC-HMS match those predicted by HEC-RAS. The control depths for the storm sewer match the corresponding depths in the main HEC-RAS model.

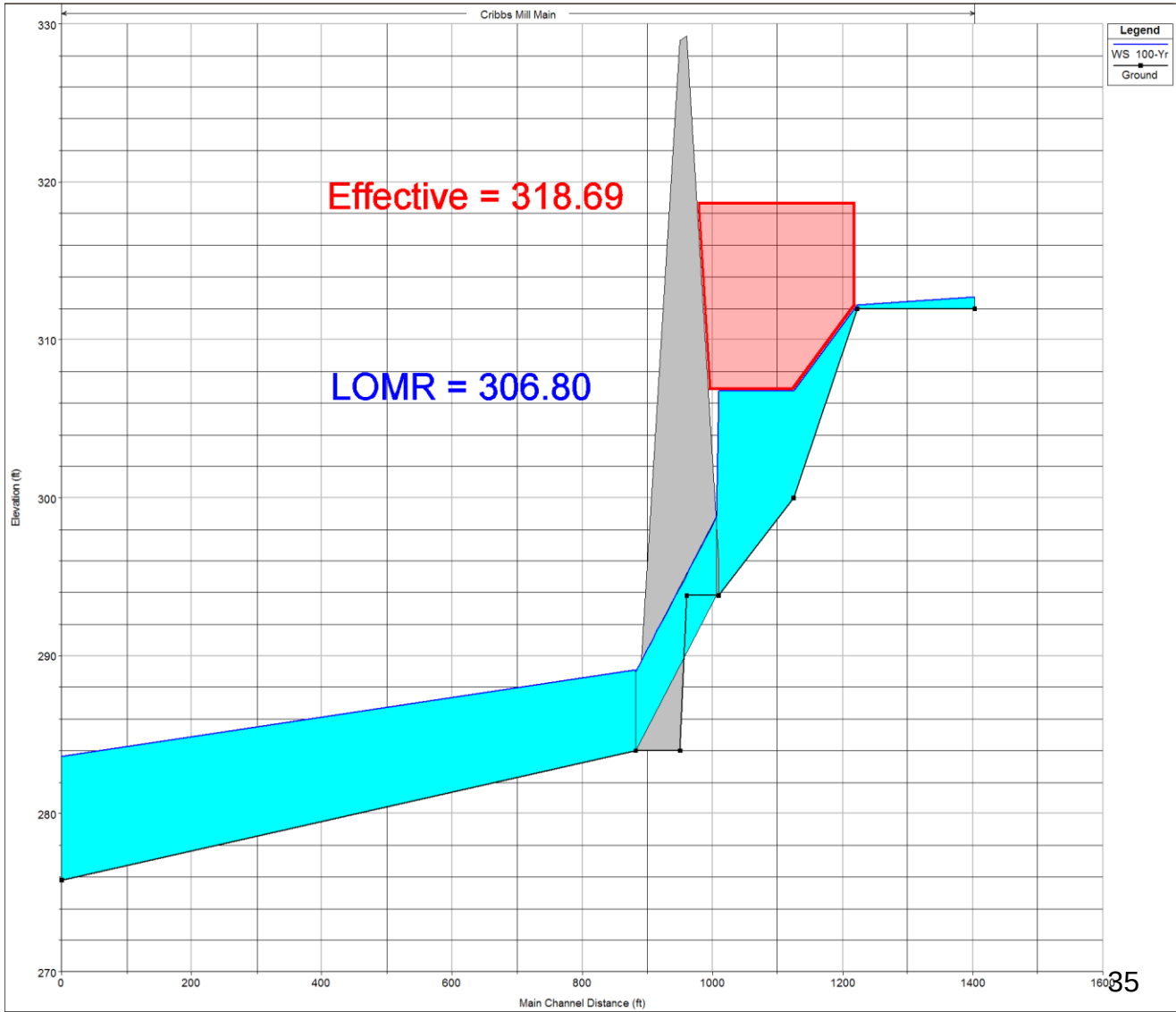
hec-ras 05 rr pond	Sta 28290	Sta 29090	Sta 29220	Sta 29340	Sta 29440	Sta 29640
LOMR 010-Yr	282.77	287.73	302.55	302.57	312.03	312.09
LOMR 050-Yr	283.38	288.80	305.60	305.61	312.12	312.46
LOMR 100-Yr	283.62	289.12	306.80	306.80	312.20	312.70
LOMR Floodway	284.22	289.37	307.63	307.63	312.79	313.44
LOMR 500-Yr	284.23	289.97	309.42	309.42	312.42	313.19
hec-ras 04 pipe				Sta 29346.16		
Storm Sewer 010-Yr				302.57		
Storm Sewer 050-Yr				305.61		
Storm Sewer 100-Yr				306.80		
Storm Sewer Floodway				307.63		
Storm Sewer 500-Yr				309.42		
hec-hms			WS 29220			
HEC-HMS 010-Yr			302.54			
HEC-HMS 050-Yr			305.61			
HEC-HMS 100-Yr			306.80			
HEC-HMS Floodway			307.63			
HEC-HMS 500-Yr			309.42			

Table 1. Summary of Water Surface Elevations.

Chapter Four Results

It really was 12 feet.

The base flood elevation dropped significantly.



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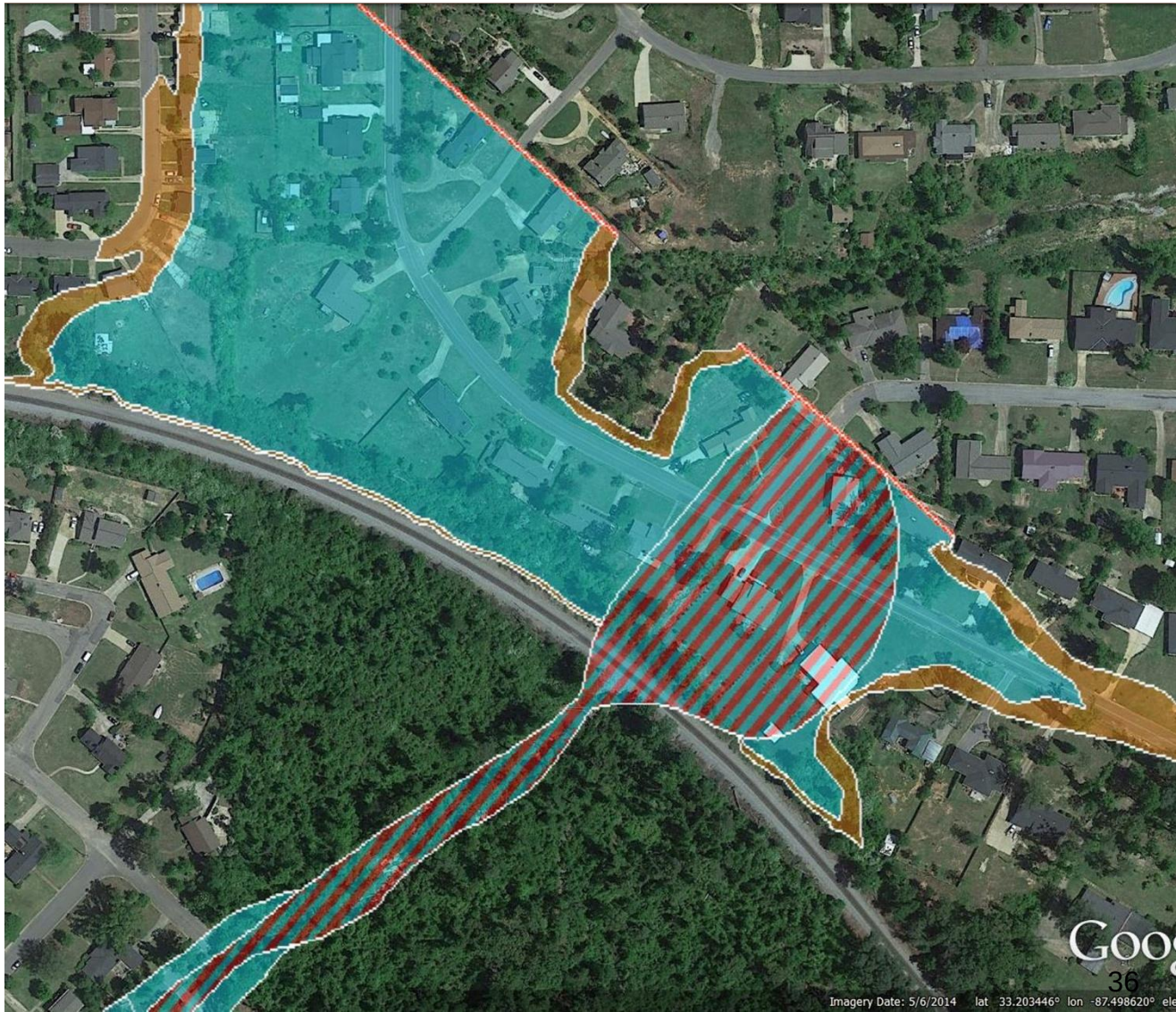
Remember this?

These were the old flood boundaries.



Chapter Four
Results

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Well, now it looks like this.

These are the new flood boundaries.

Chapter Four Results

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And it's official.

The effective date is January 15, 2015.

Federal Emergency Management Agency
Washington, D.C. 20472
September 3, 2014

CERTIFIED MAIL
RETURN RECEIPT REQUESTED

The Honorable Walter Maddox
Mayor, City of Tuscaloosa
2201 University Boulevard
Tuscaloosa, AL 35401

IN REPLY REFER TO:
Case No.: 14-04-4663P
Community Name: City of Tuscaloosa, AL
Community No.: 010203
Effective Date of This Revision: **January 15, 2015**

Dear Mayor Maddox:

The Flood Insurance Study report and Flood Insurance Rate Map for your community have been revised by this Letter of Map Revision (LOMR). Please use the enclosed annotated map panel(s) revised by this LOMR for floodplain management purposes and for all flood insurance policies and renewals issued in your community.

Additional documents are enclosed which provide information regarding this LOMR. Please see the List of Enclosures below to determine which documents are included. Other attachments specific to this request may be included as referenced in the Determination Document. If you have any questions regarding floodplain management regulations for your community or the National Flood Insurance Program (NFIP) in general, please contact the Consultation Coordination Officer for your community. If you have any technical questions regarding this LOMR, please contact the Director, Mitigation Division of the Department of Homeland Security's Federal Emergency Management Agency (FEMA) in Atlanta, Georgia, at (770) 220-5400, or the FEMA Map Information eXchange toll free at 1-877-336-2627 (1-877-FEMA MAP). Additional information about the NFIP is available on our website at http://www.fema.gov/business/nfip.

Sincerely,

Luis Rodriguez, P.E., Chief
Engineering Management Branch
Federal Insurance and Mitigation Administration

Chapter Four
Results

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Not a bad day's work.

Summary.

Background

- The Trib 7 LOMR exposed potential problems.
- It led to a City-wide investigation.

Cribbs Mill Creek

- We found that there was no documented analysis for the railroad culvert on Cribbs Mill Creek at Arcadia.

Analysis

- The large basin suggested that a peak flow analysis was not the best approach.
- We used a pond model within HEC-HMS.

Results

- We lowered the base flood elevation by almost 12 feet and removed several homes from the SFHA.

Culvert Analysis with HEC-HMS and HEC-RAS